Local capacity for energy transition in northern and Indigenous communities: Analysis of Gwich'in communities in Northwest Territories, Canada

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ABSTRACT

Introducing local renewable energy solutions into the fossil fuel dominated energy mix of many northern and off-grid Indigenous communities has the potential to create new socio-economic opportunity and address historical energy injustices. However, energy systems are comprised not only of technology and infrastructure but also the communities who generate, use, and benefit from energy. The design of local energy systems that are community appropriate thus requires an understanding of a community's socio-technical capacity, coupled with an understanding of the social processes that stimulate and sustain transitions and the longer-term, desired outcomes from local energy. This paper explores the socio-technical capacity for renewable energy transitions in northern and Indigenous communities, based on a case study of four Gwich'in communities in the Northwest Territories, Canada. Results show that the foundational attributes of socio-technical capacity for energy transition in northern communities are interconnected, and strengths or challenges in one area often reflect strengths or challenges in another. Several capacity strengths already exist to support energy transition, including community energy values inclusive of community vision and the embedded and transferable skillsets of communities, coupled with next generation leaders. In turn, there are areas where significant capacity building is required, including supports for local energy champion(s) and enabling inter-local energy networks. Results also demonstrate that recent scholarly literature regarding local capacity for community energy does not tightly align with, or reflect the nuances of, energy transition needs in northern and Indigenous communities.

Keywords: energy transition, renewable energy, northern communities, Indigenous, energy security

INTRODUCTION

Community-driven renewable energy projects are playing an increasingly important role in decentralizing the traditional, fossil-fuel dominated energy market (Leonhardt et al., 2022). Yet, the transition to renewables is uneven across the globe – particularly so in northern and remote communities that are not connected to major electricity grids (Holdmann et al., 2022). Across Canada's North, for example, there are more than 170 diesel-dependent Indigenous communities facing daily energy security challenges (Rakshit et al., 2019). Community renewable energy is high on the agenda for many rural and remote regions, especially in the Circumpolar North (Holdmann et al., 2019).

Energy systems are tightly coupled social and technical systems (Miller et al., 2015) that include not only energy infrastructure and technologies, but also the communities that use energy and either benefit from the social and economic opportunities of secure energy, or suffer from energy inequalities and injustices (Hossain et al., 2016; Urmee and Md, 2016). Transitions in energy systems are thus largely social transitions – they require changes not only in infrastructure and technologies, but in the broader social fabric of how a community interacts with energy production and consumption (Miller & Richter, 2014; Newell et al., 2017). This socio-technical relationship emphasizes the importance a community's capacity to recognize, pursue, incorporate, and govern complex and dynamic social transitions (Gui & MacGill, 2018; Miller et al., 2015). Building capacity for energy transition starts with people, not technology (Simpson et al., 2003) – especially in rural and remote regions where community energy opportunities must align with local resources, values, aspirations, and current and future capacities.

Even more complex are energy transitions in remote Indigenous communities, which face unique contemporary and historical circumstances that influence their capacity to pursue community energy initiatives (Beatty et al., 2015; Karanasios & Parker, 2018; Krupa, 2012). Many scholars have said that historically marginalized Indigenous peoples have considerable potential to lead sustainability transitions, and introducing local energy projects could address many enduring socioeconomic challenges in Indigenous communities (Karanasios & Parker, 2018; Pasqualetti et al., 2016). However, Miller et al.

(2013) emphasize that the design of energy systems that are *community appropriate* requires careful consideration of a community's socio-technical capacity to transition, coupled with an understanding of the social processes that stimulate and sustain transitions and the longer-term, desired social outcomes of transitions. Ensuring long-term success of renewable energy development in northern or remote regions requires more than building new energy projects – it requires building the local socio-technical capacity to plan for, design, pursue, implement, operate, own, and maintain renewable energy projects (Daley, 2017; Miller et al., 2018).

A major challenge, however, is that there is limited research on the necessary and sufficient socio-technical baseline capacities of remote northern Indigenous communities for energy transition. Holdmann et al. (2022) argue that notwithstanding the growth in energy scholarship and recognition of the complex sociotechnical nature of energy systems, the emphasis has largely been on global trends or disruptive technologies, downplaying the importance of place and context. Most research focused on local capacity for energy transition, internationally and in Canada, has focused on urban environments, grid-connected communities, or rural communities in developing regions of the Global south (Leonhardt et al., 2022; Rezaei & Dowlatabadi, 2016; Middlemiss & Parrish, 2010; Mühlemeier & Binder, 2017). There has been limited attention to the baseline capacity and capacity-building needs for northern and Indigenous communities to embark on such complex socio-technical transitions. Yet, understanding local capacity to support and sustain community energy in northern and Indigenous communities is foundational to planning for, initiating, and achieving long-term transitions. This means tapping into existing community capacities and identifying the needs and opportunities for capacity development.

The purpose of this paper is to better understand the socio-technical capacity for renewable energy transitions in northern and Indigenous communities. We do so by focusing on energy transition in four Gwich'in communities in Canada's Northwest Territories (NWT), though the lessons learned are broadly applicable to northern communities globally.

STUDY AREA AND METHODS

Gwich'in are one of the most northern Indigenous peoples on the North American continent, with traditional lands encompassed by the Richardson Mountains to the west and the Mackenzie Delta to the north. The Gwich'in people in the Gwich'in Settlement Area (GSA) are represented by the Gwich'in Tribal Council (GTC), operating under the Gwich'in Comprehensive Land Claim Agreement (Gwich'in Tribal Council, 2022a). The GTC vision statement characterizes the Gwich'in as a *"culturally vibrant and independent Nation that is environmentally responsible and socially, economically and politically self-reliant*" (Gwich'in Tribal Council, 2022b).

The focus of this research is on the four communities of Aklavik, Fort McPherson, Inuvik, and Tsiigehtchic (**Fig. 1**). All four communities are off-grid communities and part of the Community Appropriate Sustainable Energy Security Partnership, an initiative led by the University of Saskatchewan in partnership with northern and Indigenous communities, public and private sector enterprise, and researchers from Canada, Alaska, Sweden and Norway[1]. The Northwest Territories Power Corporation (NTPC), a crown corporation of the Government of Northwest Territories (GNWT), generates and distributes electricity in all four communities, using diesel-based generation. Electricity rates in Aklavik, Fort McPherson, Inuvik, and Tsiigehtchic are highly subsidized, with residential subsidized electricity rates at $0.306/kilowatt-hour for the first 1,000 kilowatt-hours per month from September to March, and for the first 600 kilowatt-hours per month from April to August; actual costs are $0.702/ kilowatt-hour (NTPC, 2022a).

Aklavik is powered by variable-speed diesel-based generation, delivering electricity to approximately 300 households and other (e.g., commercial, school, recreational complex) buildings, and an integrated 55-kilowatt solar photovoltaic system – installed in 2017 (**Table 1**). Approximately 51% of annual energy use in Aklavik is for heating, specifically heating oil, followed by electricity (31%) and transport (19%)

[1] https://renewableenergy.usask.ca/Projects/CASES.php.

(Arctic Energy Alliance, 2020a). Aklavik has a community energy plan, emphasizing the importance of providing residents with the information they need to make wise choices about their energy use, the need to use energy and water in harmony with the land, and to make clean, affordable, and reliable energy the everyday norm (Arctic Energy Alliance, 2020a; Arctic Energy Alliance, Natural Resources Canada, & Hamlet of Aklavik, 2017). Sustainable energy futures and encouraging youth involvement in energy planning, and training for skills and development opportunities for community members are among the hamlet's key energy goals and priorities (Arctic Energy Alliance et al., 2017).

Fort McPherson's diesel-based system is coupled with a waste heat recovery system that gathers 1,160,000 Megajoules off of the diesel generator, and an 85-kilowatt biomass project (Arctic Energy Alliance, 2020b; Cherniak et al., 2015). The biomass project was installed in 2013 to heat the Band office and community health centre with a district heat system. Transportation comprises the majority of annual energy use in Fort Mcpherson (55%), followed by heating (29%) and electricity (17%) (Arctic Energy Alliance, 2020b). Fort McPherson does not have an energy plan. The community engaged in a climate change adaptation planning project in 2011, funded by Indian and Northern Affairs Canada. Included in that plan is a vision that, by 2050, the community will be "a resilient, self-sufficient community that celebrates and practices its culture and promotes renewable economic development within its traditional lands" (Ecology North, 2011).

In Tsiigehtchic, the smallest of the four communities, approximately 47% of annual energy use is for heating, followed by electricity (32%) and transportation (22%) (Arctic Energy Alliance, 2020d). Tsiigehtchic has a climate change adaptation plan, developed in 2010 under the same Indian and Northern Affairs Canada program as Fort McPherson, and shared the same vision for community resiliency and self-sufficiency by 2050 (Ecology North, 2010).

The primary energy sources in Inuvik, in contrast, are synthetic natural gas and diesel-based generation. Inuvik's gas power plant comprised of three generators with a total installed capacity of 7.7 MW.

Liquefied natural gas is trucked in from southern Canada. The community's diesel power plant has a total installed capacity of 6.2 megawatts. There is a waste recovery unit on the power plant's natural gas-fired generator that gathers 2,510,000 Megajoules. Approximately 40% of annual energy use in Inuvik is for heating, followed by transportation (32%) and electricity (29%) (Arctic Energy Alliance, 2020c). Inuvik has a community energy plan, established in 2010, which outlines five long term goals, including increasing energy efficiency of the community, and increasing opportunities for renewable energy supply (Kavik-AXYS, 2010).

Methods

Data collection was based on semi-structured interviews with community members, Gwich'in leadership, and representatives of the energy sector and intermediary organizations. Data collection plans were tremendously impacted due to the COVID-19 pandemic, with travel restrictions prohibiting outside researchers from visiting the community. As a result, interviews with Gwich'in leadership and representatives of the energy sector and intermediary organizations were conducted remotely, via videoconference. For community member interviews, however, local Indigenous youth were hired and trained by the research team, in collaboration with the Gwich'in Tribal Council, to work as community-based researchers. The youth researchers, one per community, conducted the interviews both in person and over the phone with members of their own community. The youth researchers were significant factors in the successes of the research, especially in resolving any potential limitations of community members not wanting to speak with "outsider" researchers about their community energy experiences.

Community participants were identified using a snowball sampling approach, led by the local youth researchers. The selection of participants for the key informant interviews (leadership and other representatives) occurred in collaboration with the Gwich'in Tribal Council, through the initial identification of potential participants from which a snowball sampling approach was adopted (Lewis-Beck et al., 2011). A total of 21 interviews were conducted with Gwich'in leadership, energy sector representatives, and intermediary organizations and 74 interviews with community members (Table 2).

Interviews lasted 60 to 90 minutes and were audio recorded and transcribed. Research ethics approval was received from the University of Saskatchewan Behavioural Research Ethics Board (Beh-REB 1616) and a northern research license secured from the Aurora Research Institute (#4707) – the organization responsible for licensing research in the Northwest Territories.

Interview questions were asked as part of a larger research agenda under the CASES initiative, and thus explored several topics including: the importance of energy for everyday life in the community; challenges and opportunities to pursuing local energy initiatives; relationships between communities and utilities and intermediaries in terms of supporting energy initiatives; energy affordability and reliability; community energy needs and future opportunities from secure and sustainable energy systems; the types of local investments required to ensure a secure energy future; knowledge about the community's energy supply and energy security; human resources and expertise to develop and maintain local energy systems; future energy mix; and energy system regulations and the barriers and opportunities to support local energy.

Thus, to focus our analysis on core socio-technical capacity for energy transitions we adopted a conceptual framework developed by McMaster (2022) that proposes eight foundational attributes for the evaluation or appraisal of a community's baseline socio-technical capacity for sustainable energy transitions (**Table 3**). We define capacity simply as the collective ability of a community to create and seize opportunities to meet community needs, thus providing for greater self-sufficiency and control over social and economic futures (Smith et al., 2001). McMaster (2022) cautions that these attributes are not predictive of energy transition success, or explanatory of why some community energy projects succeed while others fail; rather, they offer conceptual guidance to the exploration of fundamental baseline capacities of a community prior to embarking on local energy initiatives. The attributes were developed based on literature exploring community energy and planning engaging Indigenous communities (e.g., Pasqualetti et al., 2016; Rezaei & Dowlatabadi, 2016; Karanasios & Parker, 2018; Stefanelli et al., 2019; Mercer et al., 2020); energy transition and community development literature focused on the Circumpolar

North (e.g., St. Denis & Parker, 2009; Rosenbloom & Meadowcroft, 2014; Cherniak et al., 2015; Poelzer et al., 2016; Mortensen et al., 2017); and research exploring socio-technical capacity in rural and remote regions of developing countries in the global south (e.g., Middlemiss & Parrish, 2010; Schäfer et al., 2011; Miller & Richter, 2014; Sovacool et al., 2020). The attributes may not be comprehensive of all factors influencing transition capacity (Vallecha et al., 2021), but McMaster (2022) argues that they capture the minimum socio-technical attributes at the community level to initiate and sustain community appropriate socio-technical energy transitions.

Using the conceptual framework as guidance, interviews were coded thematically using NVivo 12 qualitative data analysis software, with subsequent rounds of coding used to identify whether each attribute, if discussed by the participant, was referred to as an existing strength or capacity challenge or limitation in the community or region. The number of participants who identified a given attribute was also recorded across all interviews. This allowed the data to be analyzed to represent the frequency of occurrence across all participants versus the repetitive frequency within conversations. Of importance to our analysis of interview data is perspective offered by the first author, an Indigenous female scholar.

RESULTS

The sections below present results of the socio-technical capacity assessment for energy transition across the four Gwich'in communities. Results are presented holistically for each attribute as a Gwich'in region – identifying strengths and challenges across communities. Overall, *community energy values* was the most discussed attribute by interviewees, by 96% of participants and across all participant groups (**Table 4**). This was followed closely by *embedded energy skills*, identified by 83% of interviewees, and *skills development,* discussed by 77% of participants. In sharp contrast, less than one-third of participants discussed topics related to *inter-local energy networks* and *energy champions* – essential aspects of community energy leadership and local capacity to transition energy systems. The largest proportion of interviewees who raised these two attributes were those from GTC leadership, followed by intermediary organizations. These attributes were also raised by participants from the energy sector and from each the four communities, but to a lesser extent.

Based on the ratio of strengths to limitations as identified by participants when speaking to the various attributes of community energy capacity (**Fig. 2**), several important observations emerged that illustrate key strengths and key challenges to energy transition. At the aggregate scale, across the four communities, the presence of a community vision to guide energy transitions, and shared community energy values, were identified as *essential* and *existing* strengths. This was often expressed as values seen through the lens of cultural considerations, community considerations, or social and economic considerations. An additional strength identified was the presence of next generation leadership to facilitate long-term community energy transitions and ensure long-term socio-technical capacity. This was usually discussed in terms of the importance of youth involvement in community initiatives in general, but also in terms of youth interest in their energy future. A final existing strength identified was embedded skillsets – i.e. a community's existing energy knowledge. These embedded skillsets include energy-relevant skills, such as technical, managerial, or financial, skills that exist among retired community members, and the resilience of skills in terms of people's ability to adapt to new technologies or opportunities.

The two most definitive capacity challenges identified were intertwined - the first was energy literacy; the second was opportunities for skills development (**Figure 2**). Energy literacy considers both existing energy literacy within the partner communities and the access community members have to energy literacy training, workshops, and education opportunities. Skills development considers opportunities for training and capacity development, such as access to training, workshops, and education to develop skillsets relevant for energy planning and transition efforts. At the most fundamental level, these two challenges represent a lack of local access to education and training opportunities, whether for enhancing and developing energy literacy or for specific skills development in areas of expertise such as technical, financial, or managerial skillsets. Closely following these two challenges were those associated with limited development of inter-local energy networks to facilitate knowledge sharing and support across communities and with communities in other regions, and the lack of capacity to support local energy champions to drive community energy initiatives.

However, as a region, results indicate that the four communities have many opportunities, collectively, and exciting prospects to support each other's challenges and share each other's possibilities to further the region's energy planning, transitions, and developments through regional energy networks and support systems. A more nuanced analysis of results, exploring perspectives on each attribute is presented below.

Local energy champion(s)

Most interviewees who identified the importance of local energy leadership referred to current challenges – specifically the lack of people resources to provide local energy leadership. Interviewees from Tsiigehtchic, Aklavik, and Fort McPherson explained that not having designated energy champions or sufficiently resourced ones means missed opportunities to pursue renewable energy initiatives. A Tsiigehtchic participant noted the many financial programs available to support community energy, "*but we don't have anybody…that can utilize those funding pots to get started… to get that money*." GTC leadership echoed these concerns, indicating that challenges to community energy leadership are more so capacity-related than the lack of prioritization of local energy, and that "*we* [GTC] *just don't have the people and enough manpower to be able to move projects forward…or even go after all the grants that we would like to*." The scenario was different in Inuvik, the largest of the communities, where the presence of local energy champions, specifically Arctic Energy Alliance (AEA)[2], was considered a key strength for advancing local energy initiatives. An Inuvik participant explained that there is *"a staff of four or five in that Arctic Energy Alliance office, locally… those are the key people who deal with those*

[2] The Arctic Energy Alliance is a not-for-profit society with a mandate "to help communities, consumers, producers, regulators and policymakers to work together to reduce the costs and environmental impacts of energy and utility services in the Northwest Territories." (https://aea.nt.ca/)

particular issues." Although AEA's mandate is to support all communities (Arctic Energy Alliance, 2022), the AEA did not emerge in community discussions about local energy champions outside Inuvik.

Despite these challenges, GTC leadership cautioned that it should not be assumed that the communities have no local leadership to advance community energy. One participant explained that there are *"folks in each of the communities who are energy champions in their own way… in the perspective of the traditional way of life and …what they're doing in the local level, just naturally…who sets the example",* even though they may not carry an official title. A Tsiigehtchic resident shared a similar perspective, emphasizing that energy leadership is embedded in the community way of life, and that such leadership must not come from outside the community. The interviewee went on to express concern about imposed energy leadership from outside the community, notably the federal government, indicating that "*the federal government still treats us like we're in Residential School…its like, "We know what's best for you," even though [they] live in Ottawa… haven't come to our community... haven't seen the geography or the terrain, haven't spoken to our Elders, haven't spoken to our youth"*.

Inter-local energy networks

Inter-local energy networks, inclusive of communities' access to regional resources and collaborations, were described as a significant challenge by 20 interviewees. The nine participants who spoke to strengths referred more to the recognized desire to strengthen community to community and regional collaborations, versus the presence of existing networks per se. An intermediary organization suggested that strong community energy relationships do not exist across the region, explaining that "*the only time that there's sort of connection in sister communities is really, for instance, if Fort McPherson and Tsiigehtchic – one of them gets solar panels, the other one will be like, I wanna take part in that too."* The interviewee described this not as a network but rather an *"if it works there, it'll work here"* approach. This perspective was echoed by a Fort McPherson participant, identifying the desire for greater collaboration and support networks across communities but also noted the limited resources for doing so. Drawing on the community's existing biomass project, the interviewee connected the challenges to collaboration with the constraints to resourcing local energy champions, noting that *"if we had a whole department just on biomass, then that department could focus on getting the community running…and then sharing that [knowledge and experience] with the other communities."* Similar perspectives were shared by GTC leadership, noting the limited collaborations and knowledge exchanges, largely due to limited capacity to facilitate such networks and, in particular, the lack of a regional energy coordinator. Another interviewee from GTC leadership identified the complexity of working across communities on energy issues, explaining that because community energy goals and projects are locally defined "*it would look different in communities like Aklavik, which is a shared community with Gwich'in and Inuvialuit, as well as Inuvik"* than in Fort McPherson or Tsiigehtchic, emphasizing the need for regional coordination in facilitating community-to-community engagement.

Community members identified the importance of sharing energy knowledge and experience across communities but noted the importance of drawing on community expertise from outside the Gwich'in region – communities with more experience in local energy and energy transitions. For example, a Tsiigehtchic participant emphasized the importance of collaborations and learning across communities, noting: "*we could certainly learn if we visit the two communities of Colville Lake or Old Crow, where they have solar energy projects; we can certainly find out from them what kind of funding it took to get to that stage, what kind of training they offer their people."* The participant emphasized the importance of learning from community frontrunners to inform and support local energy projects. Other participants emphasized the need for improved networks between governments, not only between communities, to facilitate community-to-community learning and to share resources, innovations, and expertise. As expressed by an Inuvik participant, "*we have to seek partnership out of our – not only in the – community; maybe out of the country, as well"* and "n*ot only our territorial government, but between the Inuvialuit and the Gwich'in…to work together to mutually be beneficial…rather than against each other."*

Community energy vision

When interviewees discussed the role of a community's energy vision, most referred to the strengths of their community's existing vision for a secure energy future. Across all communities, energy cost savings was a primary focal point. For example, an interviewee from Fort McPherson spoke to viable opportunities that could come from local energy development, particularly biomass, explaining that a small biomass operation for heating the community's grocery supply store could reduce fuel-based heating bills from *"15 to 20,000 a month from November to April every year…down to about seven to 10,000."* The participant raised the up-front financial investment costs but explained that for a community's longer-term energy vision "*ten years down the road it's gonna be well worth it; it really is."* Similar drivers were identified in Tsiigehtchic and Aklavik, typically emphasizing energy cost savings. Explained by an interviewee from GTC leadership "*if you talked to the ordinary person on the street, that's what they're going to be concerned about – paying their bills…cost is going to be the primary driver."* However, GTC leadership indicated that energy cost savings is not separate from the longer-term vision of self-determination, in that "*everything else flows from that; if you have energy control locally, you can make better decisions about how you spend that energy, and what you do with it."*

Limitations or challenges associated with community energy visions were identified *only* by interviewees from the energy sector and intermediary organizations, who emphasized a lack of energy vision in the region and a lack of cohesion. When an energy sector participant was asked about community energy vision, the participant indicated that energy transition challenges in the region are rooted in energy vision challenges, in that a cohesive and collective vision is lacking: *" it comes back to that vision…we're not seeing a cohesive group."* One intermediary spoke of the benefits of a strong community energy vision, from energy sustainability and security to improved health, but emphasized the *"encouraged dependency"* that exists as a result of colonization. The interviewee suggested that to expect a community to articulate a clear energy vision is not realistic because: *"People have been encouraged to be* *powerless…to suddenly expect people to turn around and become independent…is not realistic; it takes time."*

Community energy value

This attribute relates to how energy systems (new or existing ones) are understood to interact with or add value to existing socio-cultural and economic values in the communities. Community values, inclusive of a community's social and cultural values, were raised by 83 interviewees as a significant factor in driving energy transitions, whereas 25 individuals spoke to existing challenges of energy options in supporting community values. Environmental values, reinvesting in the community, independence, and preserving cultural values and practices were dominant topics of conversation. An interviewee from GTC leadership indicated that most community members are environmentally concerned, they "*want things done with climate change and global warming, just being stewards of the land… they want to see cleaner sources of fuel that we're using to heat our homes and drive our vehicles and everything."* But, for most community members, the dominant theme was the added value to communities from having a secure and affordable energy, to ensure that more of a community's resources are available for *"going back into the economy and into the schools…there'd be programs and money to fund programs... for the community*." For example, an Inuvik participant emphasized that at the core of community energy is the opportunity to improve community services, such as daycares, schools, and recreational centers – all of which are highly-valued community services – explaining that "*if you could lower their operating costs, they could deliver more programs/services."* Participants from other communities and GTC leadership echoed this perspective, noting the day-to-day value that local energy developments could bring to communities and the larger opportunities it would create – specifically, supporting greater self-determination and breaking the *"long history of colonial policies and colonial approaches telling us how we need to do things."*

Closely related, participants across all four communities emphasized preserving the land and maintaining cultural values as prominent factors when discussing community values toward energy – values that need to be supported under any energy mix. For example, an interviewee in Fort McPherson explained that wood is important for home heating, because sometimes some people don't have jobs and can't afford the fuel oil. However, even community members who use wood for a heat source still need fossil fuels – they still need affordable fuel for their skidoos to harvest that wood, or for generators at cabins or when out on the land. The participant also raised the importance of fossil fuels for Elders within the communities, noting that *"diesel is important, especially for people that are Elders and people that and need heat and…for people that don't have stoves, they need that diesel."* That said, the affordability of fuel to support local way of life and access to the land was a concern raised across all communities. A participant from Inuvik spoke to the effects of energy costs on hunters and trappers, noting that "*a lot of our hunters and trappers can't go hunting and that because the cost of gasoline is too high. I've got a boat, but I don't use it as much as I used to because the price of gas is quite costly. I know a lot of our elderly hunters and trappers that want to get out there, they can't afford to. It's just too expensive."*

Interestingly, of the 25 individuals who also referred to concerns or challenges regarding the local value of pursuing renewable energy, 21 were community members. For example, a participant from Aklavik offered a lukewarm perspective on the value of the community's solar array and future investments in renewables, in that "*they setup solar panels a while ago, haven't seen much change though."* An intermediary offered an explanation for this criticism, suggested that some community members were upset after the solar farm development but this may have more to do with a poor project planning process than local values about renewables per se, emphasizing that *"the community has to live with it, they need to know about it, they need to want it, they need to approve it or else it's just not right."* That said, in speaking about current energy needs and the value of renewables in Tsiigehtchic, an interviewee commented that "*if you're gonna be going hunting, trapping, or fishing, the only energy you're using is your snowmobile, your boat, which is not really energy."* This may reflect how participants who are critical of the value added of investing in renewables understand their energy system, disassociating the high costs of energy for electricity and home heating from the cost savings potential of renewables and the subsequent income now available for other energy uses. All interviewees from Tsiigehtchic, Fort

McPherson, and Inuvik who raised concerns about the community value of renewables described negligible impacts, positive or negative, of energy transition on traditional practices.

Energy literacy

Energy literacy, inclusive of communities' access to energy literacy programs, was described as a challenge by 38 interviewees; 14 spoke to existing strengths. Interestingly, those who spoke to strengths were representatives of either GTC leadership, intermediary organizations, or the energy sector – but even those participants were conservative about the level of energy literacy that exists in communities. An interviewee from GTC leadership explained that most community members understand that diesel is a main fuel source for community heating, but beyond that most would not understand the details of how the system actually worked. Another interviewee referred to Aklavik's integrated solar array, noting that everyone in the community knows that it exists, but *"no one knows what they are"* and there is limited understanding of the energy supply chain from source to home.

The deficit of energy literacy programming across communities was identified as a major challenge. A GTC leader identified only the efforts of the AEA on raising awareness about energy use and emissions, but no broad-scale community energy literacy initiatives. Similar concerns were evident from community members in Aklavik, Fort McPherson, and Tsiigehtchic. For example, a community member emphasized *"we can't keep relying on non-renewable energy like oil and gas, it's not good for the planet"* but went on to indicate that greater efforts are needed to improve energy literacy: *"if we could start having our kids thinking of those, maybe we can not only cut down on the climate change, but I think we could really have a community that thinks energy efficient."* Responses were different in Inuvik, where community participants indicated that there has been much energy literacy programming. This may suggest an imbalance across the Gwich'in communities in terms of access to energy literacy opportunities; as one community member noted: "*they've (AEA) done a lot of workshops, but I just don't think the message is getting out there*." From participants across all communities there was criticism of the dominate scope of energy literacy programming on energy efficiency, rather than also promoting a better understanding energy production, distribution, use, and alternative technologies. This was reinforced by one study participant who explained that "*a lot of the energy literacy…tends to focus on how to conserve energy in your house, changing the LED lights, that kind of thing; that kind of energy literacy is good of course, because you're reducing your energy consumption…but it really doesn't help people understand how electric power systems work in the first place."*

Embedded skills

When interviewees referred to embedded skillsets within communities, most identified them as existing capacity strengths. When challenges were raised, it was primarily by interviewees from intermediary organizations. In Aklavik, Fort McPherson, and Tsiigehtchic, multiple interviewees raised specific skillsets within the community, such as technical, managerial, or retired skillsets that could support local energy initiatives. In Tsiigehtchic, for example, participants mentioned how one community member had taken solar panel installation training and was passing that knowledge on to other community members. An Aklavik participant spoke to the resilience of technical skillsets, especially for the community's diesel-based generator, in that "w*e have everything in house…we have our own techs.*" The interviewee explained that it's not necessary to have such skillsets in every community, and that *"it's only on special stuff that we bring in people…like to do the generator re-windings - that goes out every 3 or 4 years, so it just wouldn't make sense to hire someone to stay there."* An interviewee in Fort McPherson noted local technical skills related to biomass (e.g., training on the woodchipper) but emphasized the lack of business development skillsets, explaining "*let's say we wanna do a proposal, then we'd have to get the consultants to help do that."* Interestingly, another community member provided an opposite perspective, indicating uncertainty as to whether the community had sufficient technical skills but emphasized existing and retired business skill sets to manage energy projects: "*there are many people that have managed businesses, and lots of people that have qualifications and training to help with that".* Participants in Inuvik offered similar observations, identifying retired individuals with electrical and other trades who could provide the skills for simple solar installations: "*people who have retired but have certain trade* *skills like electrical… that would be useful for doing stuff simple as setting up solar panels at a cabin, for instance.*"

Transferable skills also emerged as a dominant capacity strength, especially skills from the mining and oil and gas sector, with a community member suggesting that "*there are a lot of people with a lot of really good skills here that they've developed for heavy equipment operators or drilling…that are very easily transferable; they could be retrained into working in renewable energy."* This perspective was echoed by GTC leadership: *"There's definitely people who I think have the ability to be able to be trained very quickly…specifically [those] who have worked in the oil and gas field and probably dropped out of school when they were about 15; when oil left, there was no jobs, so there's definitely a lot of people who have past experience in more technical kind of jobs whose skills could just be upgraded."* Another community participant noted that transferrable skills could mean recognizing even greater impacts from energy transitions, as individuals can find new employment opportunities - "*they just need the training to transfer over."*

Skills development

Interviewees from all four communities spoke to the importance of and need for greater local access to training opportunities, from how to maintain biomass boilers, to solar designs and installations, to wind, waterpower, electrical and other trades. In addition to technical skills, participants identified the need for developing better capacity in financial and business skills to secure and manage energy projects, with an Inuvik participant noting "*our Band has struggled in the past with our business deals"* and went on to emphasize that *"we need to invest in ourselves".* Local accessibility of training programs, however, was a significant challenge raised by almost all participants. An interviewee from Inuvik reports that there are solar installers in the region who will sometimes help train local people during installations or "*help find funding for them to go down south to be more well-versed."* However, a community member from Tsiigehtchic identified a sharp contrast between the smaller communities and Inuvik:

"There's nobody that comes into the community or even has phoned our office and said, "We're based in Inuvik." Or "We're based in Yellowknife, and we're taking care of your community, and we want you to know that we have so much money in our budget for your community, and is there people that we can be talking to, to access this program?" Nobody does that training."

Interestingly, an interviewee from an intermediary organization indicated *"there are programs that exist,"* such as through the Arctic Energy Alliance and Indigenous Clean Energy Network, and GTC has partnered with these organizations. For an interview from GTC leadership, however, a major constraint was that most formal skills development programs require an educational level that makes the programs largely inaccessible to local community members, such as "*incentives for studying at a master's level when we don't have anyone,"* noting that few to no opportunities or incentives seem to be available for people to receive technical training that aligns with local needs. The participant went on to explain that for those people *"who are getting to the Masters level...then they're not really interested in coming back here,"* which does little to build local capacity. In Aklavik, Fort McPherson, and Tsiigehtchic, community interviewees emphasized the importance of more informal training and local mentorship – specifically, community members being trained by other community members who have received formal training. For example, an interviewee in Fort McPherson referred to an individual trained to operate the woodchipper for biomass energy, and the opportunity to provide hands-on training to other community members, especially youth, noting that "*the training part is not in the youth's mind right now, but once they get going, it'll flow*."

Next generation leaders

Few interviewees focused specifically on the role youth in their community could play regarding energy futures, but when the topic did emerge the majority referred to youth as next generation leaders and a current strength in their community. The strength of future leaders was identified by participants from each of the four communities, by intermediary organizations, and by Gwich'in leadership. An intermediary participant explained that the renewable energy sector is growing in the North; referring to Aklavik's solar energy installation: *"if you are a student and you've never seen a solar system and all of the sudden you get one, and it peaks your interest, it might encourage you to follow that as a career."* Gwich'in leadership participants also spoke to the value of having an example of a community renewable energy project accessible to youth in terms of sparking their interest to pursue energy-related careers. One participant referred to the high school in Fort MacPherson, which is heated by biomass, noting *"that's an example right where they are where renewable energy is happening right in their community."*

Gwich'in leadership participants also spoke to existing opportunities within communities to engage youth in renewable energy and energy efficiency, noting existing science, technology, engineering and mathematics (STEM) projects taking place in the schools, from the ages of preschool to high school. One participant noted the work of GTC leadership to help recruit youth into careers in the energy sector, by providing scholarships and bursaries to be trained as engineers and more technical positions rather than for office-based positions. Another interviewee commented on a recent initiative with the Northwest Territories Power Corporation, to *"provide for more apprentice type training positions for those right out of high school."*

The regional Gwich'in youth council, which has a youth representative from each community, was identified as an example of next generation leadership capacity. A Gwich'in leader explained that the youth council members attend academic conferences each year, and they have a high success rate of youth council members attending post-secondary education. The initiative targets youth who have recently graduated high school but haven't attended post-secondary. After the first four years of the program, 83% of participating youth have gone to a post-secondary program, an internship, or some sort of education or training. As explained by an interviewee from GTC leadership, investment in next generation leaders *is "helping young people be aware of their responsibility especially as Indigenous people and specifically Gwich'in….we were all taught a very deep responsibility to be a part of our communities and to give back, and if you have the ability to do so, then it's your responsibility to do so."*

DISCUSSION

This research identified socio-technical capacity strengths and challenges across Gwich'in communities. Results indicate several attributes where a strong baseline capacity for energy transition exists, such as community energy values, inclusive of community vision; or the embedded skillsets of the communities, coupled with opportunities for strengthening community energy knowledge and next generation leaders. But there are also areas where capacity building is needed for community energy transition, such as supports for local energy champion(s) and enabling inter-local energy networks. Reflecting on the relative opportunities, strengths, and actor perspectives across the Gwich'in region, we offer several key observations regarding the capacity for long-term socio-technical energy transitions in northern and remote communities that are applicable across context and foundational to ensuring community appropriate, sustainable energy transitions.

Interconnectedness of socio-technical capacity attributes

Based on results from our study region, the foundational attributes of socio-technical capacity for energy transition in northern communities are interconnected and strengths or challenges in one area often reflect strengths or challenges in another. For example, successful energy transitions often hinge on communities identifying value from energy planning or from specific energy projects, which may hinge on available and sufficiently resourced local energy champions (Hoicka et al., 2021; Krupa, 2012) – a noted capacity deficit in the study region. In turn, however, if communities have not articulated the potential value of community energy, beyond energy conservation measures, it may be difficult to identify passionate leaders from within the community to drive transitions (Middlemiss & Parrish, 2010; van der Horst, 2008; Walker & Devine-Wright, 2008).

Similarly, noted deficiencies in energy literacy (e.g., education, programming) and skills development opportunities (e.g., technical skills training) appear tightly coupled. Arguably, deficits in either one reflects or causes deficits in the other – without opportunities for training and capacity development it is challenging to nurture strong energy literacy programs in communities (Arctic Council & Sustainable Development Working Group, 2019; Rosenbloom et al., 2016); without energy literacy programs, it is challenging to advance technical skills development to support transitions (Holdmann et al., 2019; Lovekin et al., 2016). Unfortunately, deficits in energy literacy programming and skills development opportunities may translate to deficiencies in the future embedded skill sets of a community (Bhattarai & Thompson, 2016; Mortensen et al., 2017; Pasqualetti et al., 2016), and in next generation leaders to maintain community energy projects and energy transitions in the longer-term (McCarthy & Morrison, 2020; Nelson, 2019; Yazdanpanah et al., 2015). Further, if communities lack knowledge about energy or if widespread misinformation exists, it can obstruct transitions and diminish its social value (Mercer et al., 2017).

Capacity building alignment with community values and aspirations

There are often diverging perspectives between community members and other interests, including intermediaries, about community energy capacity, priorities, and challenges. In this research, the views of community members differed from those of other participants regarding local access to energy literacy and training programs, and the skills development and training needed to pursue community energy. Through successful transitions in Alaskan communities, for example, energy literacy programs were seen as essential for helping community members understand energy systems and how they can reduce costs (Holdmann et al., 2019). Interestingly, in this research, community member concerns about local opportunities for energy literacy programming and for hands-on training (i.e., apprentice mentorship) in energy systems installations and maintenance often contrasted with the perspectives of other participants, who spoke of the variety of programs and their availability across the Gwich'in communities. This divergence may reflect misalignment between the types of energy literacy and training programs available versus what communities consider appropriate for their energy future. For example, though intermediaries, the energy sector, and leadership often spoke of energy efficiency and energy use education, community members emphasized the need for knowledge and training about energy production and distribution and how to secure external funding for new energy initiatives, as opposed to programs focused on using less energy.

Recent scholarship indicates that limited access to energy literacy education in the North, coupled with limited locally available technical training programs, poses significant barriers to community energy transitions (Cherniak et al., 2015; Mercer et al., 2017). Our results indicate that equally important to program access is that such programs align with community needs, values, and aspirations. In absence of local capacity that reflects local values, energy projects can be implanted, and values attempted to be reshaped by other interests, resulting in energy futures or priorities that may not succeed in the long term or serve to maximize economic or social value to the community (Ikejemba et al., 2017; Tenenbaum et al., 2014). In this research, interviewees from the smaller communities of Aklavik, Fort McPherson, and Tsiigehtchic, but not necessarily the larger center of Inuvik, often spoke of energy intermediaries or the federal government as "outsiders." This is not surprising, as Canada's history reflects systemic differences of values, priorities, and often a divide between what Indigenous communities want versus what external interests believe is *best* for Indigenous communities. Focusing on community-appropriate capacity building, aligning with the values and interests of the communities, is essential for a successful, long-term sustainable socio-technical energy transition.

Sister communities as energy support networks

There are numerous examples of the opportunities that can emerge from inter-local community energy networks. In Wales and Scotland, for example, energy cooperative programs have been most successful in networks of close-knit rural communities (Strand, 2018); while in Alaska several regional grids have emerged and utilities have developed systems for supporting regional energy planning and project maintenance across otherwise remote locations (Holdmann et al., 2019). Similarly, in the global south, research has shown the value in community-to-community mentorship for developing renewable energy projects in rural areas and providing a network for knowledge transfer (Ulsrud et al., 2018). Such community-to-community relationships provide support and enable communities to share success stories and lessons learned of energy transition efforts (Cherniak et al., 2015). Strengthening sister community relationships within and external to the Gwich'in region may be a solution to many local capacity challenges. A strong inter-local energy network among communities can allow for capacity deficits in one community to be leveled out by the collective capacity strengths of networked of communities (Berka et al., 2020; Onyx & Leonard, 2011; Shaw, 2017). For example, if Aklavik does not have a locally resourced community energy champion, they may leverage the strengths of the other partner Gwich'in communities; or, as the larger of the four communities, if Inuvik has certain embedded energy technology skills, there is an opportunity for knowledge transfer and training to build similar skillsets on other communities.

There is a cohesive regional interest in our study area in developing partnerships and knowledge-sharing platforms, and a shared interest in future inter-local energy networks. However, some of the reason for the limited energy networking and knowledge transfer among the four communities currently may be because they are each at relatively similar stages of energy transition – thus emphasizing the importance of sister community relationships that extend beyond the Gwich'in territory. Ulsrud et al. (2018) explains that such relationships allow inter-local learning to occur about specific socio-technical experiences in different geographical contexts sharing contextual similarities, whereby the lessons and experiences with energy projects or innovations, including new skill sets, are transferred to other settings. Many participants in our research indicated the importance of learning from other communities in the Northwest Territories that have embarked on local energy initiatives, and especially the opportunity to learn from neighbouring Alaskan communities who are recognized as leaders in community energy transition solutions. Such networks can build local capacity through community-to-community learning, even in absence of more formal training programs locally, and support more collaborative energy planning, technology transfer, resource sharing, and transition opportunities.

Northern context in contrast to community energy scholarship

Energy transitions are accompanied by social shifts, emphasizing the importance of understanding local capacity to recognize, pursue, incorporate, and governing such complex and dynamic social transitions (Feurtey et al., 2016; Miller, O'Leary, et al., 2015; Miller & Richter, 2014; Newell et al., 2017). However, this research demonstrated that recent scholarship regarding local capacity for community energy does not always tightly align with, or reflect the nuances of, energy transitions in northern and Indigenous communities. This was evident in three areas.

First, the importance of local leadership in community energy is well established in the literature, with the lack of local energy champions identified as among the most significant challenges to energy transition in the North (Axon et al., 2018; Cherniak et al., 2015; Menghwani et al., 2022). We agree that such community-level leadership with formal professional and technical skills is important to secure the financial and technical resources for energy projects and to establish and maintain important energy support networks with external actors (Ghorbani et al., 2020; Martiskainen, 2017). That said, the lack of formally designated community energy leaders may be constraining but it should not be assumed that the communities have no local leadership to advance community energy. As emphasized by participants in this research, there are energy champions in each community that may not carry an official title but are energy champions through their traditional way of life – promoting community well-being, environmental and cultural awareness, and thus mobilizing the social capital necessary to support energy transitions. This understanding of energy champion(s) as community social and cultural leaders should be considered when approaching energy leadership in communities in the North, in addition to the more formalized understandings of community energy leadership.

Second, recognizing the social value of energy is critical to transition efforts (Jenkins et al., 2018). The dominant focus of much of the community energy literature however, including energy policy and the efforts of energy intermediaries in our study area, is often on energy efficiency and emissions reduction (Government of Canada, 2016; Hossain et al., 2016) with much less consideration for how such initiatives generate social and cultural value for communities. In this regard, energy transitions are often criticized for reflecting external or top-down values (Stefanelli et al., 2019), omitting the importance of cultural and social values in shaping energy transition in northern Indigenous communities (Krupa, 2012). An overarching emphasis in the conversations we had with community members was the importance of energy for the entire community – emphasizing the importance of energy transitions that create new social value and economic opportunity, generating new energy to support community growth, and creating new resources to invest in local programs and services.

Third, literature often focuses on the capacity deficits of northern and Indigenous communities (Stevenson & Perreault, 2008), emphasizing the skill sets that are missing rather than also focusing on the resilience of existing skills and the value and diversity of community experience. The community energy literature consistently refers to the importance of professional skills and training programs and the lack of skills or skill deficiencies in many communities as barriers to energy transition (Advanced Energy Centre, 2015; Cherniak et al., 2015; Mortensen et al., 2017). But in this research, participants discussed the value of hands-on learning-by-doing from existing and retired skillsets, passing their knowledge on to others in the communities, as important embedded skills, and an overarching strength across. It should not be assumed that northern and Indigenous communities lack the knowledge and skills to embark on energy transitions. Important to understanding local capacity is the resilience of skillsets in a community to adapt and be transferred to new types of energy systems and transition efforts.

CONCLUSION

This research aimed to understand the socio-technical baseline capacity for renewable energy transition in Gwich'in communities in Northwest Territories, Canada. In doing so, this research serves to advance knowledge and create opportunities for other northern and Indigenous communities to inform the exploration and assessment of their own baselines, energy futures, and opportunities for energy transitions. Building on the scholarly literature and drawing on the lessons from on-the-ground assessment, this research provided insight to the socio-technical baseline capacity challenges and strengths of remote, northern Indigenous communities for embarking on energy transitions. The results paint a complex regional picture of multiple strengths and challenges across communities and socio-technical attributes and illustrate the interconnectedness of many socio-technical capacity attributes for enabling energy transitions. Our results also illustrate often diverging perspectives on socio-technical capacity strengths and challenges between community members and other participants, but also differences between the smaller, more isolated communities and the larger community of Inuvik. Strengthening sister community relationships within the region to share skills and resources and building new relationships with communities outside the region to learn from community energy innovators, are foundational to building local socio-technical capacity for local energy transitions. However, a cross-cutting lesson emerging from our research is that capacity building opportunities, from local energy leadership and education to skills development and youth engagement, must be shaped by local community values, needs, and desired energy futures.

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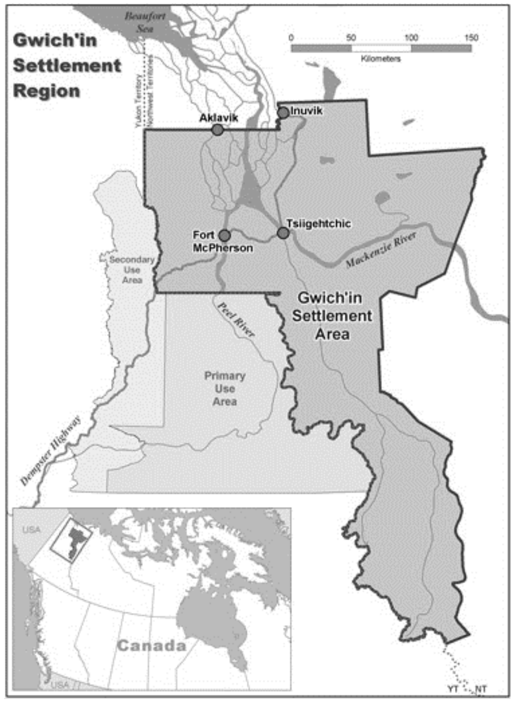

Figure 1: Gwich'in Settlement Area (Gwich'in Renewable Resources Board, 2022).

Table 1: Community socio-economic and energy profiles: Aklavik, Fort McPherson, Tsiigehtchic, Inuvik.[1]

Community	Socio-economic profile[2]	Energy profile[3]

Aklavik	▪ Population: 684 [24% < 15 yrs; 14% > 60 yrs]
	▪ Employment: 41.2%
	▪ Average family income: $92,467
	▪ Residential tenure: 222
		▪ Diesel-based generation: four 320 kw generators
		▪ 55 kw solar PV system
		▪ Residential heating: heating oil, firewood
		▪ Renewable energy: 4.2%
		  ○ 4% firewood (190 cords)
		  ○ 0.2 % (59,900 kilowatts-hours) solar PV

Fort McPherson	▪ Population: 737 [15% < 15 yrs; 22% > 60 yrs]
	▪ Employment: 39.5%
	▪ Average family income: $81,700
	▪ Residential tenure: 242
		▪ Diesel-based generation: 1.83 MW plant
		▪ Biomass district heating: 85 kw facility for community buildings
		▪ Residential heating: heating oil, firewood
		▪ Renewable energy: 4.01%
		  ○ 2% (236 tonnes) wood pellets
		  ○ 2% (196 cords) firewood
		  ○ 0.01% (4,100 kilowatt-hours) solar PV
		▪ Waste heat recovery system: 1,160,000 MJ

Tsiigehtchic	▪ Population: 190 [16% < 15 yrs; 15% > 60 yrs] ▪ Employment: 53.4% ▪ Average family income: $110,500 ▪ Residential tenure: 60	▪ Diesel-based generation: three diesel units, 510 kw ▪ Residential heating: heating oil, firewood ▪ Renewable energy: 5% ○ 100% firewood (68 cords)

Inuvik	▪ Population: 3,303 [22% < 15 yrs; 14% > 60 yrs]
	▪ Employment: 68.3%
	▪ Average family income: $126,832
	▪ Residential tenure: 1,180
		▪ Diesel-based generation: installed capacity 6.2 megawatts
		▪ Gas power plant
		  ○ 3 LNG-fueled generators (7.7 MW)
		  ○ trucked-in LNG fuel
		▪ Residential heating: natural gas, firewood
		▪ Renewable energy: 3.4%
		  ○ 2% (787) cords from firewood
		  ○ 1.3% (600) tonnes from wood pellets
		  ○ 0.1% (180,000 kilowatt-hours) solar PV
		▪ Waste heat recovery system: 2,510,000 MJ

[1]Sources: (Arctic Energy Alliance, 2020a, 2020b, 2020c, 2020d; Cherniak et al., 2015; NTPC, 2022a, 2022b, 2022d, 2022e; NWT Bureau of Statistics, 2022a, 2022b, 2022c, 2022d).
[2]Population based on 2021 data; employment and residential tenure based on 2019 data
[3]Renewables as % of energy mix based on most current (2018) data

Table 2: Research participants.

Participant Group	Participants	Number
Aklavik	Community members	14
Fort McPherson	Community members	20
Inuvik	Community members	25
Tsiigehtchic	Community members	15
Gwich’in Leadership	Gwich’in Tribal Council leadership	10
Energy Sector	Utility representatives	2
Intermediaries	Intermediary organizations	8
		Total: 94

Table 3: Core attributes of socio-technical capacity for early-stage planning and assessment of community energy transitions.

Community energy champion(s)

- Individuals or groups (e.g., energy planner) with mandate to lead community energy initiatives, who are sufficiently resourced - financial, logistical, technical, managerial.

Inter-local energy networks

- Local access to a network of professional and technical knowledge about energy technologies and innovations, including formal or informal opportunities for community-to-community learning and mentorship from energy community frontrunners.

Community energy vision

- A broadly shared vision, focused on longer-term goals and aspirations (e.g., self-determination, socio-economic independence) whereby community energy is seen a pathway to help achieve those goals and aspirations.

Community energy value

- Community energy is understood as adding local value, creating new opportunities for social cultural, and economic value creation or enhancing existing ones.

Energy literacy

- Foundational knowledge about energy use, energy sources, and energy technologies, coupled with access to energy literacy programs and learning opportunities.

Embedded skills

- Existing and transferable energy-related skill sets in a community to pursue, operate and maintain local energy systems or technologies.

Skills development opportunities

- Availability of and access to training or mentorship programs across energy skill sets, and an interest in the local workforce to pursue energy-related training and employment.

Next generation leaders

- Energy education is embedded in school curriculum and community youth are actively engaged in local leadership, community initiatives, or local energy projects and activities.

Source: McMaster (2022); McMaster et al. – under review

Table 4: Social capacity attributes as a strength vs challenge, across the four study communities, to support community energy transition.

Social Capacity Attributes	**Perspectives on current capacity**[1]	
	strength	*challenge*
Local energy champion(s)	*6*	*12*
Inter-local energy networks	*9*	*20*
Community energy vision	*7*	*4*
Community energy value	*83*	*25*
Energy literacy	*14*	*38*
Embedded skills	*59*	*29*
Skills development	*19*	*62*
Next generation leaders	*13*	*4*

[1] Number of interviewees who identified current capacity strengths or challenges. Numbers for any given combination of 'strengths' and/or 'challenges' (rows and/or columns) do not add to the total (n = 94) because not all interviewees addressed every attribute. For a given attribute, some individuals identified *both* strengths and challenges.

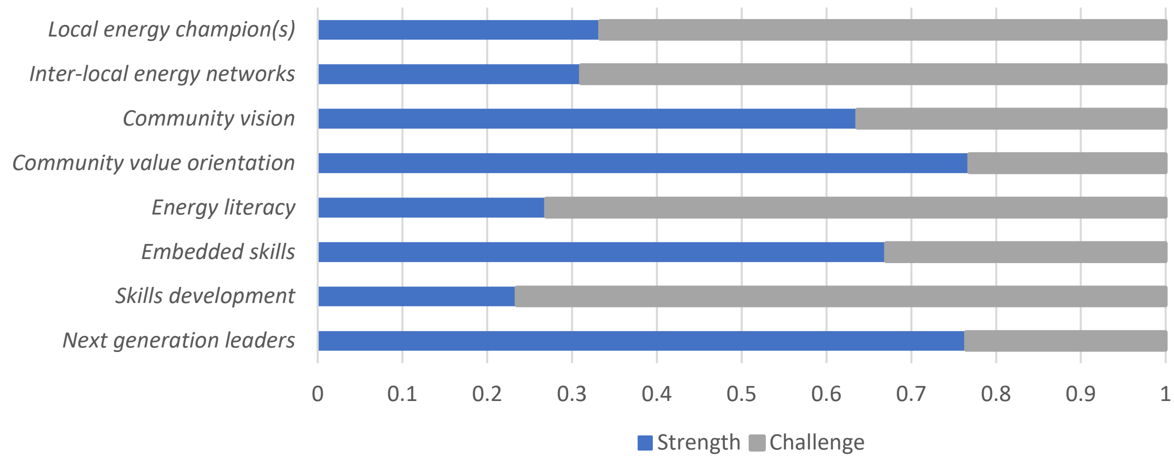

Figure 2: Ratio of baseline community capacity strengths to limitations for the study region, as derived from interview data. Ratio is based on the number of times an attribute was described as a strength vs. limitation, with some interviewees describing an attribute as both a capacity strength and limitation.

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Table 2: Research participants.

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Table 4: Social capacity attributes as a strength vs challenge, across the four study communities, to support community energy transition.